

# A new integrated and seamless Map of the Americas

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**Abstract:** Implementing a participatory approach, the Pan-American Institute of Geography and History (PAIGH) is building an integrated, homogeneous and harmonized 1:250,000 vector cartographic database in the region to provide the territorial foundation for studies directly related to PAIGH's Pan-American Agenda and to contribute to the achievement of the UN Sustainable Development Goals. The participatory approach is supported by the CAF-Development Bank of Latin America, in the context of the GeoSUR Program, with the technical advice of the National Center for Geographic Information of the National Geographic Institute of Spain (CNIG, acronym in Spanish), the National Geography Institutes of the region, and contributions from the United States National Section of the PAIGH (Department of the Interior, U.S. Geological Survey, and the U.S. Agency for International Development). The fundamental datasets that are being harmonized across the international borders include: administrative boundaries, settlements, roads, land morphology, toponymy and hydrography, which are key geographic features relevant to natural and cultural processes that affect territorial and environmental management and climate change. The geographic specialists from the official National Geographic Institutes have worked together in participative workshops to integrate their official geospatial data to produce two sub regional datasets which are available to the community: the "Integrated Map of Central America" and "Integrated North Andean Map". The source of the geospatial databases from Central America include: Belize, Costa Rica, El Salvador, Guatemala, Honduras, southern Mexico, Nicaragua and Panama, and from the North Andean area: Bolivia, Colombia, Ecuador, Peru and Panama. The completed product of harmonized regional datasets at 1:250,000 scale are available as a Web Mapping Service (WMS) through the GeoSUR portal (<http://www.geosur.info/geosur/index.php/en/>) in compliance with OGC and ISO/TC 211 standards. The technical specifications, catalog of geographic objects

and representation catalog documents are available on the website. Future plans include coordinating the project to extend throughout South America with the participation of Brazil and the southern cone of South America. Additional products will include an integrated hydrographic network to monitor stream flow and direction.

Keywords: Integrated, Map, Americas, PAIGH, CAF, GeoSUR

## 1. Background

Monitoring environmental change on a global scale requires cooperation between nations. With the large number of weather related natural disasters occurring in the Americas, there is a great need to make seamless geospatial data for disaster planning and environmental monitoring. These disasters have had enormous repercussions upon economic, environmental and social development. As natural disasters do not respect political or administrative boundaries, the source and destruction may cross borders requiring multinational cooperation. To make this cooperation effective, nations need to share and make compatible environmental, geographic, and demographic data at a level that promotes collaboration but does not compromise national security.

During a disaster, various sources of geospatial information are extremely useful, yet all require the need to build upon an official cartographic database such as the official data from the geographic institutes of each country. Achieving a unified map base at global level was an objective pursued by the international Global Map initiative. The member countries of PAIGH contributed to the Global Map with the Americas Global Map Working Group (MGA) in 2005, at a working scale of 1:1,000,000. The objective was achieved partially through the project “Integration of Global Map Data of South America” which was completed in 2012 (Hunt 2012).

In order to address the needs of the region, integration of data at a larger scale with greater levels of detail was the next step. This initiative was presented initially through a request to the Pan-American Institute for Geography and History (PAIGH) in 2009 and took shape as the “Integrated Map of Central America” initiative at 1:250,000 scale (Norori et al. 2013). The Integrated Map of Central America (IMCA) was built by applying participatory mapping methods to build working relationships between geographers and natural resource specialists of Central America while building a seamless map of the region at the 1:250,000-scale that can be distributed to partner organizations in the region (see figure 1).

The ICMA project included four technical participatory workshops held between 2011 and 2014 in Costa Rica and El Salvador. Having the participation of the technical specialists from the official geographic or cartographic institutes responsible for the official cartography of the countries of Central America and



In 2014, building upon the Central American initiative, the project “Integrated North Andean Map (MIAN)” was launched with the participation of the Geographic Institutes of the northern part of South America; Colombia, Ecuador, Peru and Bolivia. Panama was included as a link to the project ICMA. For this phase of the project, the National Center for Geographic Information of Spain (CNIG) provided the leading guidance and the USGS provide the technical assistance and the Development Bank of Latin America (CAF) provided the funding.

In May 2016, the fourth workshop of the MIAN was held at the Brazilian Institute for Geography and Statistics (IBGE) in Rio de Janeiro, providing an opportunity to introduce the participatory process to Brazil's official Geography Institute, IBGE. This provided the foundation for beginning the next phase of the project titled "Integrated Map of South America" (MIAS). This fourth workshop introduced the process of developing an integrated hydrographic network with topographic data.

Integrating the seamless maps of Central America and the first version of the Integrated North Andean Map produced an official continuous and harmonized cartographic geospatial database, approved by participatory consensus of the 12 nations in Central and South America, using official data sources.

For the next phase of the project, the first workshop of the Project for the Integrated Map of South America (MIAS) was held from the 7th to the 10th of November 2016 in Asuncion with the participation of delegates from the Geographic Institutes of South America, establishing continuity to this project with the objective of achieving an Integrated Map of the Americas.

The WMS service for the cartographic base of the MIAN (Rodríguez 2016) is available in the regional viewer of the GeoSUR Program (see figure 2). It has a licence agreed upon by the member countries; this is of the type CC BY 4.0, which allows free use and requires only the mention of the source in the following way: CC BY 4.0 CAF, PAIGH, Geosur Program, IGM Bolivia, IGAC Colombia, IGM Ecuador, IGTG Panama, IGN Peru.

All of the initiatives conceived and put into effect through the Integrated Map projects of Central America, the MIAN and the MIAS lead to the fulfillment of an overall objective, the shaping and creation of the Map of the Americas.



**Fig. 2.** The WMS MIAN in the regional viewer of the GeoSUR Program



**Fig. 3.** Accumulated extent of the Integrated Map of Central America, the MIAN and the recent inclusion of Brazil

## 2. Objectives

### 2.1 General Objective

The general and essential objective of the project is to produce by working cooperatively in a participatory process the first integrated digital map of geo-spatial data at 1:250,000 scale based on official data from the countries of the American continent.

The concept of integration refers to a digital map with geometric and semantic continuity with a single, seamless model. For example there are no technical differences when crossing from one country to another apart from those that derive from differences in the real world.

## ***2.2 Specific Objectives***

The specific objectives of the workshops were to:

- Sponsor technical workshops for integrating and harmonized across borders the official geospatial data at 1:250,000, provided by the Geographic Institutes of each participating country.
- Reach consensual agreements about: Technical Specifications, Object Catalogue, UML Model, Data Policy, Metadata, Users Licence, among others.
- Produce standardized technical documentation that complements the product: product specifications, object catalogue, portrayal catalogues (MIAN Project 2016) and other documents (articles, presentations, etc.).
- Perform an outreach campaign to spread awareness of the project in blogs, social net works and e-mail lists, in addition to conference events.
- Publish the official cartographic bases set up and agreed up for the project, united in a single dataset by means of a WMS service that can be seen in the Regional Viewer of the GeoSUR Program <https://www.geosur.info>
- Provide a foundation to build upon best geospatial practices products, and services that act in complement to the integrated maps, such as a topological network of the hydrography linked to the hydrographic basins, a catalogue of names, WFS services, download services, etc.

## **3. Format of the Participatory Workshops**

Representatives of the PAIGH, GeoSUR, and technical specialists from the CNIG (Spain) and USGS have moderated the participatory workshops. Technical specialists in cartography and geography representing the Geographic institutes of the member countries have played a critical role to define common standards and feature content for the data integration between countries (see figure 4).

For the Central America workshops, only the technical specialists from each country participated. Beginning with the MIAN project, the Directors of the participating institutes attended the start of the workshops with their technical specialists to provide management support and time commitments for the data integration. Technical specialists provided their own laptops for the workshops. The host institute provided staff to support the workshop logistics and additional technical experts. Speakers for special topics were invited to provide new capacity and

technical practices. At the fourth MIAN workshop, the Brazilian institute of IBGE was invited to witness the participatory process.

In general, the workshops were scheduled for an entire week from Monday to Friday with 6 and 7 hours of work per day. A coordination meeting was normally held the Sunday before the workshop with participants from the PAIGH, GeoSUR, USGS, CNIG and the local organizing committee.



**Fig. 4.** From left to right and from above downwards; 1st, 2nd, 3rd and 4th MIAN workshops

As preparation prior to the workshops, a set of survey questions were distributed to the institutes in order to gather detail concerning the specifications of the data that each country would provide to the project. At each start-up workshop the Directors of the participating geographic institutes were present to demonstrate their commitment and form a multinational working group. Each country gave presentations about the main features of their official cartographic databases.

Initially for each of the geographic regions of the projects, the general framework defined the tasks and reached consensus concerning the first version of specifications and the Object Catalogue. Next, work began on harmonizing the geographic features crossing the international boundaries, normally beginning with the hydrographic features. For each theme, the features and Object Catalogues were defined by consensus of the participating countries.

As the workshops continued, the participants defined the complete catalogue of geographic objects, structured by themes, objects and attributes, to build a conceptual model in UML. Significant progress was made on harmonizing the geographic features that crossed the international borders, leaving some specific issues to be resolved before the next workshop.

In the months between each workshop, CNIG personal monitored the data integration progress and reviewed the quality of the work. For the networked hydro-

graphic integration process, each country was tasked to network the flow direction of the hydrographic features to prepare the data for the network flow routines as defined by the USGS.

Per consensus agreement was made concerning the Catalogue of Geographic Objects, the UML Model and the product specifications. Additionally the metadata was produced in accordance with the LAMP (Latin American Metadata Profile). This resulted in PAIGH adopting the LAMP metadata profile as a standard. The Military Geographic Institute of Ecuador produced a set of documents outlining the process. The harmonization of the contour data theme was problematic. Therefore the participants decided to use the Shuttle Radar Topographic Mission (SRTM) dataset to create homogeneous contour data for the continent. The official topographic data was represented by elevation control data points.

Participants proposed that the data and process would be on a five year revision schedule. The WMS service would adopt a CC BY 4.0 license.

Thus far, the workshops have been a success in completing the defined objective. Specific tasks were completed in the periods between the workshops. Most importantly, for each region, a collaborative team of technical experts from the participating countries developed a high level of professional and personal cooperation.

## 4. Methodology

### 4.1 Input Data for the MIAN Project

**Table 1.** Sources of data from each Geographic Institute in the MIAN project

Organization	Resolution	Production Process	Date of the data	Estimated accuracy
IGN Bolivia	1:250,000	Conversion to digital media over Landsat 7 and adaptation to existing data	2013	$\pm 50$ m
IGAC Colombia	1:250,000	Generalization of 1:100,000 data	2013	$\pm 75$ m
IGM Ecuador	1:250,000	Generalization of 1:50,000 data and binational cartography at the frontiers	2014	$\pm 50$ m
IGNTG Panama	1:250,000	Generalization and update of 1:50,000 data	2014	$\pm 30$ m
IGN Peru	1:100,000	Photogrammetric restitution	2014	$\pm 50$ m

Most geographic institutes in the project provided digital geographic data at 1:250,000, scale, except some of them, such as Peru and Colombia which have data at 1:100,000 that had to be generalized and simplified to a greater or lesser degree (see table 1 about the MIAN).

## **4.2 Data Policy**

The leading authorities of the participating institutes agreed to adopt a data policy for the Web Map Server (WMS) based on a Creative Commons Attribution licence (CC BY 4.0),<sup>1</sup> which allows for all types of use, with the condition that the authorship and intellectual property of the data be recognized with the following statement (example in the case of the MIAN):

CC BY 4.0 CAF, PAIGH, GeoSUR Program, IGM Bolivia, IGAC Colombia, IGM Ecuador, IGNTG Panama, IGN Peru.

This data policy was produced with the aim of facilitating the maximum possible use and publishing an open service that can be utilized by any user, for any purpose and in all types of activities and projects.

Moreover, it was also agreed that the geographic representation of the International boundaries of the countries were only approximate reference marks as guidance and have no official status nor validity as official boundaries, in accordance with Chapter I, article 1 of the Organic Statutes of the PAIGH (PAIGH 2014).

## **4.3 Work Methodology**

During these workshops, all aspects relevant to the project were debated until consensus was reached by all participants. The data were distributed among the multi-national teams in order to deal with the final editing of the harmonized information across country boundaries. At all times each participating institute kept its rights and control over its data, so that all the modifications made were officially approved.

During the periods between the workshops, work was done via telephone meetings, electronic mail and the exchange of data and metadata files. The CNIG were responsible for checks on the geometry, the logical consistency and identifying residual problems needing to be corrected.

The methodology of work was based on a series of general principles accepted unanimously:

- Debate and discussion of the key aspects.
- Decisions taken by consensus.

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<sup>1</sup> <https://creativecommons.org/licenses/by/4.0/>



- Conformance with the ISO 19100 (ISO 2016) standards, the OGC (OGC 2016) standards, recommendations from the PAIGH and standards from widespread sources.
- Use of the images from Landsat 7 and when available from Landsat 8 as reference images.
- Full use made of the experience in similar projects in Europe provided by the experts from the CNIG.
- Full use made of the experience of the USGS in creating Hydrography graphs.
- Transfer of the data to the CNIG to be checked and verified between workshops.
- Work on successive stages of improving the quality.

The work was structured as a series of tasks performed sequentially to maintain the logical process:

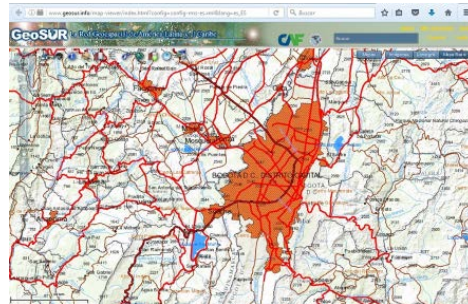
- Survey on the data availability in order to gather information about the datasets to integrate and identify, as far in advance as possible, potential or possible problems, such as variations in resolution, divergencies in the models, differences in the quality or in the updating schedules, etc.
- Agreement on data product specifications in accordance with the ISO 19131 standard, which was agreed upon in a first draft which later will be refined during the process. The specifications include the name of the product, an acronym, a reference resolution, a Coordinate Reference System, a UML Model, a Catalogue of geographic objects structure by themes, objects and attributes, a schedule of updates, certain metadata, etc.
- Choice of data for each country, in a process that may be a delicate issue when there are several datasets available in a geographic institute at a scale close to the reference scale and with differing properties (some data being more current, other data with better geometry, etc.). The facilitators of the project played an observation role while empowering the technicians to make the decisions.
- For purpose of cartographic reference, technicians accepted a non-official International line between countries as an approximate guide for reference for transborder integration of data. A reference note with the data identifies this non-official line as a line without validity of judicial, legal, administrative properties. The official boundary between countries was not addressed during the workshops as this is a diplomatic issue.
- The geometry of the first themes that were integrated for cross border harmonization were hydrography, highways and settlements, in that order. In general, this phase is the one that requires the most work and that takes up more hours per person, due to the large quantity of situations that it is necessary to resolve interactively in a participatory manner (see figure 4).
- Detection and checking of errors. During the intervals between workshops, the CNIG proceeded to perform checking routines on the geometry and to-

pology, report errors and propose to each organization a possible solution for each situation detected.

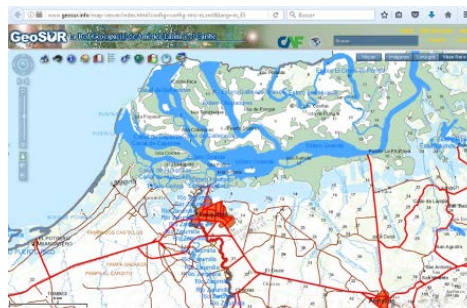
- Correction of errors. During the time between the workshops, each geographic institute was requested to correct the topology and geometric problems which normally only contained residual errors.
- Adding additional themes (control points, points of interest) under the category of miscellaneous, which includes all the Points of Interest (PoI) of many types to provide cartographic portrayal for the digital map.
- Creation of a hydrography network modeled after the USGS National Hydrography Network. This process assigns a flow direction to all water features.
- Drafting of the metadata, which, in accordance with the Latin American Metadata Profile (LAMP), describes the data in one metadata record for each country, together with an additional record of metadata for the whole MIAN dataset. Thus there is a series of units for data from the countries integrated into the map. The WMS service will also be catalogued when this becomes available.
- Publication of the WMS (see figures 5 and 6 as examples of the MIAN), together with a WMTS version, using agreed upon symbology. The USGS under the cooperative framework of the GeoSUR program hosts the final WMS of the harmonized data for the different projects.



**Fig. 5.** Highways of the MIAN countries and Brazil



**Fig. 6.** Web Map Service of the Integrated North Andean Map



**Fig. 7.** Viewing the Integrated North Andean Map

## 5. Conclusions

The Central America and North Andean countries have successfully completed the geospatial data harmonization between the neighboring countries to create a continuous mult-national standardized map using official data sources. The data is made available in two WMS's: one for Central America and the other for the North Andean countries, in the regional viewer<sup>2</sup> of the GeoSUR program. The data is accompanied by metadata, which defines the data sources, data specifications, and the object and symbolization catalogs.

The future steps of the project are to harmonize the MIAN and the Integrated Map of Central America, and to extend the synergy for the participatory process to all of South America and the North American countries of Canada, US. and Mexico. The South American portion of the project took the first steps during a workshop held in Asuncion, Paraguay in November 2016.

Along these lines, the extension of the resources available and related to this project include:

- A networked hydrography database with chain-node topology, navigable, and continuous linked to the hydrographic basins. A networked hydrography database will greatly facilitate cross border cooperation for water resources and for disaster management.
- A geographic catalogue or index, based on the objects and their names as agreed upon during the workshops. This will allow search tools and services based on official data sources.
- Opening the possibility of providing access to download the data in an open format and in accordance with the licences and conditions of each one of the participating geographic institutes.
- The implementation of new OGC services such as Web Feature Service (WFS), WFSWeb Coverage Service (WCS), and Web Processing Service (WPS), WCS, WPS, etc, with growing capabilities and enhanced functions.

The advantages of using a participatory collaborative process to harmonize official data sources in a multi-national arena are:

- 1) Use of official data sources that are reliable, sustainable and produced by the geographic institutes of the region who are custodians of the cartographic databases.
- 2) The participatory process provides an environment of consensus to build agreements between the involved parties. This guarantees results using best practices in the sector using the most widely-shared recommendations and the most standardized and consolidated procedures.
- 3) Conformity with the ISO 19100 standards and with OGC specifications, supported under the directives and guidelines of the PAIGH.
- 4) The European experience of the CNIG through decades long participating process to integrate European maps.

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<sup>2</sup> [http://www.geosur.info/map-viewer/index.html?config=config-rms-es.xml&lang=es\\_ES](http://www.geosur.info/map-viewer/index.html?config=config-rms-es.xml&lang=es_ES)

- 5) The USGS experience in creating the National Hydrography Dataset and the Archydro model.
- 6) Importantly, the Directors and technical staff of the geographic Institutes involved have developed close working relationships and agreed upon the commitment update the data and process every five years.
- 7) Longterm sustainability and maintenance of the project with the support of the PAIGH and of CAF, to connect the MIAN, the Integrated Map of Central America and a future Integrated Map of South America and hopefully North America.
- 8) All of the users of geospatial information in the region – those involved in making decisions, in planning, and in research (both students and professionals) – will benefit from this initiative, as will other multinational initiatives, such as the SDI of the Americas and the activities of UN-GGIM of the Americas.

This initiative is of strategic significance, as it contributes fundamentally to the creation and publication of basic geographic data also referred to as reference data, which cross international boundaries as a cornerstone and reliable foundation for all geographic information. It is an essential resource for facing the major global challenges of the 20<sup>th</sup> century, such as climate change and sustainable development.

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